Information Sciences

Decomposition Algorithm for Global Reachability on a Time-Varying Graph

This method sequentially solves a series of small problems instead of a single large problem.

NASA's Jet Propulsion Laboratory, Pasadena, California

A decomposition algorithm has been developed for global reachability analysis on a space-time grid. By exploiting the upper block-triangular structure, the planning problem is decomposed into smaller subproblems, which is much more scalable than the original approach.

Recent studies have proposed the use of a hot-air (Montgolfier) balloon for possible exploration of Titan and Venus because these bodies have thick haze or cloud layers that limit the science return from an orbiter, and the atmospheres would provide enough buoyancy for balloons. One of the important questions that needs to be addressed is what surface locations the balloon can reach from an initial location, and how long it would take. This is referred to as the global reachability problem, where the paths from starting locations to all possible target locations must be computed.

The balloon could be driven with its own actuation, but its actuation capability is fairly limited. It would be more efficient to take advantage of the wind field and "ride" the wind that is much stronger than what the actuator could produce. It is possible to pose the path planning problem as a graph search problem on a directed graph by discretizing the space-time world and the vehicle actuation.

The decomposition algorithm provides reachability analysis of a time-varying graph. Because the balloon only moves in the positive direction in time, the adjacency matrix of the graph can be represented with an upper block-triangular matrix, and this upper block-triangular structure can be exploited to decompose a large graph search problem. The new approach consumes a much smaller amount of memory, which also helps speed up the overall computation when the computing resource has a limited physical memory compared to the problem size.

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Autonomous GN&C for Spacecraft Exploration of Comets and Asteroids

An integrated autonomous guidance, navigation, and control capability is developed for enabling precision small-body close-proximity operations and touch-and-go sampling.

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A spacecraft guidance, navigation, and control (GN&C) system is needed to enable a spacecraft to descend to a surface, take a sample using a touch-and-go (TAG) sampling approach, and then safely ascend. At the time of this reporting, a flyable GN&C system that can accomplish these goals is beyond state of the art. This article describes AutoGNC, which is a GN&C system capable of addressing these goals, which has recently been developed and demonstrated to a maturity TRL-5-plus.

The AutoGNC solution matures and integrates two previously existing JPL capabilities into a single unified GN&C system. The two capabilities are AutoNAV and G-REX. AutoNAV is JPL's current flight navigation system, and is fairly mature with respect to flybys and rendezvous with small bodies, but is lacking capability for close surface proximity operations, sampling, and contact. G-REX is a suite of low-TRL algorithms and capabilities that enables spacecraft operations in close surface proximity and for performing sampling/contact. The development and integration of AutoNAV and G-REX components into AutoGNC provides a single, unified GN&C capability for addressing the autonomy, close-proximity, and sampling/contact aspects of small-body sample return missions.

AutoGNC is an integrated capability comprising elements that were developed separately. The main algorithms and component capabilities that have been matured and integrated are autonomy for near-surface operations, terrain-relative navigation (TRN), real-time image-based feedback guidance and control, and six degrees of freedom (6DOF) control of the TAG sampling event.

Autonomy is achieved based on an AutoGNC Executive written in Virtual Machine Language (VML) incorporating high-level control, data management, and fault protection. In descending to the surface, the AutoGNC system uses camera images to determine its position and velocity relative to the terrain. This capability for TRN leverages native capabilities of the original AutoNAV system, but required advancements that integrate the separate capabilities for shape modeling, state estimation, image rendering, defining a database of onboard maps, and performing real-time landmark recognition against the stored maps.

The ability to use images to guide the spacecraft requires the capability for image-based feedback control. In AutoGNC, navigation estimates are fed into an onboard guidance and control system that keeps the spacecraft guided along a desired path, as it descends towards its targeted landing or sampling